

Lasers – A Benefaction to Implant Dentistry

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Abstract: Lasers have been used for many years in implant dentistry. In some indications, laser treatment has become state of the art as compared to conventional techniques. The use of surgical lasers has been advocated to aid in the placement and second stage recovery of dental implants, together with soft tissue contouring. In addition, laser use has been suggested as an aid in decontamination of the implant surface in cases of peri-implantitis. Lasers also have helped clinicians to overcome several complications and patient's discomfort. Today, many types of lasers wavelengths are available for clinical usage. The aim of this article is to introduce the reader to laser application in implant dentistry and address many of the advantages of this type of treatment. This article is a comprehensive review of new laser applications in implant dentistry.

Key Words: Lasers, implants, osteotomy, laser welding.

I. Introduction

The origins of implant dentistry can be traced back to China 4000 years ago when bamboo was inserted into the jaw bone for fixed tooth replacements¹. Goldberg and Ghershkoff in 1949² marked the beginning of modern implant dentistry, with the description of the technique for the subperiosteal implant. In 1985, the publication of Tissue- Integrated Prostheses: Osseointegration in Clinical Dentistry by Branemark et al³ ushered in the era of osseointegration. They introduced the concept of gental surgical insertion technique for placement of highly biocompatible titanium implants.

The province of prosthodontics has come a long way from the domain of replacing missing teeth by complicated and time consuming mechanical procedures to inexhaustable and boundless generation of modern technology. One such technology that has been a cutting edge in the field of prosthodontics is Lasers. Laser is the acronym for "Light Amplification by stimulated emission of radiation" named by GORDON GOULD in 1957⁴. In 1960, Theodore Maiman⁵, a scientist with the Hughes Aircraft Corporation, developed the first working laser device, which emitted a deep red-colored beam from a ruby crystal. During the next few years, dental researchers studied possible applications of this visible laser energy

Studies in the 1970s and 1980s turned to other devices, such as CO2 and neodymium YAG (Nd:YAG), which were thought to have better interaction with dental hard tissues. The medical community in the mid to late 1970s had begun to incorporate lasers for soft-tissue procedures, and oral surgeons added the technology in the early 1980s. Frame⁶, Pecaro⁷, and Pick⁸ cited the benefits of CO2 laser treatment of oral soft-tissue lesions and periodontal procedures.

In 1990, Myers and Myers⁹ received the US Food and Drug Administration's permission to sell a dedicated dental laser, a Nd:YAG device for intraoral soft tissue surgery. In time other laser wavelengths such as Argon, Ho:YAG and Er:YAG laser was investigated and numerous instruments have been made available for use in dental practice and more are being developed^{10,11}. Both lasers and implantology are considered to be the fashionable treatments of modern dentistry, and combining them seems to represent best practice from a number of perspectives. Implantology is one of the many dental indications for the use of lasers, and it is one from which patients can benefit significantly. many laser wavelengths have become available and have gained popularity in different aspects of dentistry. Recently, the use of laser systems has become increasingly popular in dental implantology.

II. Laser Types

Depending Upon The Wavelength:

Light Source	Wavelength	Use
UV Light	100nm-400nm	Not used in dentistry
Visible Light	400nm-750nm	Most commonly used in dentistry e.g Argonand Diagnogent laser
Infra-red	750-100000	Most dental lasers are in this spectrum

Depending Upon Duration Of Laser Emission:

- Continuous wave (CW)
- Single pulsed (normal mode) lasers

- Single pulsed q-switched lasers
- Repetitively pulsed or scanning lasers
- Mode locked lasers

Depending Upon The Tissue They Penetrate:

TYPE OF LASER	EXAMPLE
Soft tissue laser	KTP ,Diode, Nd:YAG, CO ₂
Hard and Soft Tissue Lasers	Er:YAG, Er:Cr:YSSG

Depending Upon Hardness:

Soft Lasers: With a wave length around 632nm. Soft lasers are lower power lasers. These soft lasers generally utilize diodes and the manufacturers claim that these lasers can aid healing of the tissue, reduces inflammation, edema, and pain.

- Helium-neon (He-N) at 632.8 nm (red, visible).
- Gallium- arsenide (Ga-As) at 830 nm (infra-red, invisible).

HARD LASERS (Surgical lasers) : Hard lasers induce a direct reaction with tissue through absorption. They are used in surgery, for germ and bacteria reduction.

- Argon lasers (Ar) at 488 to 514 nm
- Carbon-dioxide lasers (CO₂) at 10.6 micro-meter
- Neodymium-doped yttrium aluminum garnet (Nd:YAG) at 1.064 micrometer.
- Holmiumyttrium-aluminum-garnet (Ho:YAG) at 2.1 micro-meter.
- Erbium,chromiumyttrium-selenium-gallium-garnet (Er,Cr:YSGG) at 2.78 micro-meter.
- Neodymiumyttrium-aluminum-perovskite (Nd:YAP) at 1,340 nm.

Depending Upon The Type Of Active / Lasing Medium Used :

Solid State Laser: In this kind of lasers solid state materials are used as active medium. The solid state materials can be ruby, neodymium-YAG (yttrium aluminum garnet), Er:YAG, Er:Cr:YSGG.

Gas Laser: These LASERS contain a mixture of helium and Neon. It acts as active medium. CO₂ and Nitrogen LASER can also be made.

Dye or Liquid Laser: In this kind of LASERS organic dyes like Rhodamine 6G in liquid solution or suspension used as active medium inside the glass tube.

Excimer Laser: Excimer Lasers (the name came from excited and dimers) use reactive gases like Chlorine and fluorine mixed with inert gases like Argon or Krypton or Xenon. This LASERS produce light in the ultraviolet range.

Chemical LASER: A chemical laser is a laser that obtains its energy from a chemical reaction. Examples of chemical lasers are the chemical oxygen iodine laser (COIL), all gas-phase iodine laser (AGIL), and the hydrogen fluoride laser, deuterium fluoride laser etc.

Semiconductor LASER: In these lasers, junction diodes are used. These are known as injection laser diodes. Whenever the current is passed, light can be seen at the output.

Classification Of Lasers:

According to ANSI and OSHA standards lasers are classified as:

Class I- These are low powered lasers that are safe to use. e.g. Laser beam pointer

Class II- Low powered visible lasers that are hazardous only when viewed directly for longer than 1000 seconds, e.g. He-Ne lasers

Class II b - Low powered visible lasers that are hazardous when viewed for more than 0.25 seconds.

Class III a - Medium powered lasers that are normally hazardous if viewed for less than 0.25 seconds without magnifying optics.

Class III b - Medium powered lasers that can be hazardous if viewed directly.

Class IV - These are high powered lasers (> 0.5 W) that produce ocular skin and fire hazards.

Advantages of Lasers¹²:

- It is painless, bloodless that results in clean surgical field, and fine incision with precision is possible.
- There is no need for anaesthesia if at all anaesthesia has to be administered, then it needs to be used minimally only.
- The risk of infection is reduced as a more sterilized environment is created as the laser kills bacteria.
- No postoperative discomfort, minima lpain and swelling, generally doesn't require medication.
- Superior and faster healing, offers better patient compliance.

Disadvantages of Lasers¹³:

- Lasers cannot be used to remove defective crowns or silver fillings, or to prepare teeth for bridges.
- Lasers can't be used on teeth with filling already in place.
- Lasers don't completely eliminate the need for anaesthesia.
- Lasers treatment is more expensive as the cost of the laser equipment itself is much higher

Characteristics of Lasers Used In Implantology:

CO₂ LASER:

CO₂ laser was first time developed by Patel et al. in 1964¹⁴. CO₂ laser have a wave length of 10.6 microns, are gas and fall into the far infra-red into the spectrum. All CO₂ lasers works in non-contact mode. CO₂ lasers have an affinity for wet tissues regardless of tissue color. They are highly absorbed in oral mucosa, which is more than 90% water, although their penetration depth is only about 0.2 to 0.1mm. There is no scattering, reflection, or transmission in oral mucosa. Hence, what you see is what you get. CO₂ lasers reflect off mirrors, allowing access to difficult areas. Unfortunately, they also reflect off dental instruments, making accidental reflection to non-target tissue a concern. As CO₂ lasers are invisible, an aiming helium – neon (He Ne) beam must be used in conjunction with this laser. One of the limitation of this laser is the penetration depth is approximately 0.2 to 0.3 mm.

Nd: YAG Laser:

Here a crystal of Yttrium – aluminum – garnet is doped with neodymium. Nd: YAG laser, has wavelength of 1,064 nm (0.106 μ) placing it in the near infrared range of the magnetic spectrum. Nd:YAG laser was first developed by Geusic in 1964. A crystal of yttrium-aluminum- garnet doped with neodymium is used and they are invisible similar to CO₂ laser, have infra-red range on spectrum. It is not well absorbed by water but are attracted to pigmented tissue. Eg: hemoglobin and melanin. Therefore various degrees of optical scattering and penetration to the tissue, minimal absorption and no reflection. Most dental Nd: YAG lasers work in a pulsed mode. At higher powers and pulsing, a super heated gas called a plasma can form on the tissue surface. It is the plasma that can be responsible for the effects of either coagulation, vaporization or cutting. If not cooled (e.g. by running a water stream down the fiber) the plasma can cause damage to the surrounding tissues.

DIODE LASER: Indium-Gallium-Arsenide-Phosphide-Ingaasp (Diode); Gallium-Aluminum-Arsenide-GaAs (Diode); Gallium-Arsenide - GaAs(Diode) :

It has wavelength range of 635 to 950 nm, utilizing flexible quartz fiber; it is absorbed by pigmentation of the soft tissue. Thereby making diode laser an excellent hemostatic agent. Diode is used for soft tissue removal in contact mode, giving tactile sensation similar to electro cautery. Tissue penetration is less than comparable Nd:YAG effects, with potential for heat damage to underlying bone reduction^{15,16}. The Nd:YAG beam is readily absorbed by amalgam, titanium and non-precious metals, requiring careful operation in the presence of these dental materials. The depth of penetration has been estimated to be 2 +_ 1 mm in soft tissue.

ARGON LASERS:

Argon lasers are those lasers in the blue-green visible spectrum. They operate at 488nm or 514.5nm, are gas like CO₂ lasers and are easily delivered fiber optically like Nd:YAG. Argon lasers have an affinity for darker colored tissues and also a high affinity for hemoglobin, making them excellent coagulators. It is not absorbed well by hard tissue, and no particular care is needed to protect the teeth during surgery. The blue wavelength of 488 nm is used mainly for composite curing, while green wavelength of 510 nm is mainly for the soft tissue procedures and coagulation¹⁷.

ERBIUM:YAG LASER:

In 1997 with FDA safety clearance erbium: YAG laser have been practiced on hard tissue like enamel, cementum, bone. Er:YAG laser has not been extensively used for the soft tissue applications. Helium neon laser is utilized as aiming beam in the fiber optic delivery system. Er:YAG laser has a wavelength of 2,940 nm, which is said to be ideal for absorption by hydroxyapatite crystals and water. This wavelength causes water to evaporate into steam, being irradiated resulting micro-explosion of the hard tissue¹⁸. Water spray is used to wet the surface during laser radiation to achieve maximum efficiency of tissue removal with minimum heat generation.

Er:Cr:YSGG LASER (Erbium: Chromium: YSGG): Also known as water-laser (marketed as Bio-laser in the USA), works by Hydro-kinetic tissue cutting system using laser power to energize water for the use on hard and soft tissues.

Ho: YAG LASER (Holmium YAG lasers): It has a wavelength of 2,100 nm and is a crystal. It is delivered through a fiber optic carrier and a He-Ne laser is used as an aiming light. Like Nd: YAG, can be used in both the contact and non-contact modes and are pulsed lasers. Ho: YAG laser has an affinity for white tissue and has ability to pass through water and acts as a good coagulator.

Use Of Lasers In Removal Of Granulation Tissue Prior To Implant Placement

One of the most important uses of lasers in implantology is the removal of granulation tissue and disinfection of the surgical area after extraction. Erbium lasers can be used for this purpose, especially if there was chronic infection before the extraction, regardless of whether implants or bone grafts are being placed. It has even been suggested that implants can be placed at pre-infected sites, although the site has to be cleaned thoroughly. Owing to significant differences in water content, the erbium laser can be used to only remove soft tissue by setting the parameters correctly (energy density, pulse duration, etc.). This is done without thermal side-effects on the bone, and with greater comfort to the patient while disinfecting the surface, since no force is applied, unlike with curettes.

Lasers as Haemostats

A good percentage of older patients are on anticoagulant therapy because of some cardiological conditions. In such cases laser hemostasis is a boon over conventional techniques. Nd:YAG has been very effective in this field as it has penetration depth of 4mm in soft tissues. In a clinical study in 44 patients by Horch and Deppe¹⁹, bare laser technique was used, and to reduce the thermal effects, a pulsed laser was used. It was concluded that intra-alveolar application of pulsed Nd:YAG laser energy can be considered safe.

Laser Aided Osteotomy

Traditionally used techniques in bone removal have involved handpieces, bone files, etc. But, now precise bone cutting can be obtained with the Er:YAG laser and CO2 laser. Lasers can not only be used to establish a controlled incision of overlying gingival tissue and to initiate a breach of the cortical bone plate, prior to the use of conventional implant drills but can also be used to prepare osteotomy site, where, there is no need for exertion of pressure on the bone, which could be an advantage when performing an osteotomy. The cause of concern while performing osteotomy is rise of temperature and bone implant contact after implant placement. During osteotomy procedures, an increase in temperature of the bone increases the risk for developing postoperative complications. Possibility of overheating the bone is high when conventional drill systems are used due to difficulty in getting the coolant between the drill and the bone²⁰.

Eyrich G²¹ compared the super-pulsed CO2 laser at 9.6 µm to the Er-YAG laser and the conventional drill with regard to their respective thermal effects on human bone. Therefore, temperature rise during ablation of human bone was measured. The results of the study suggested that a maximum rise of mean temperature to 1.88°C (well below the critical range of 7°C) demonstrated the safety and tissue-preserving capability of the super-pulsed 9.6-µm CO2 laser. Stübinger S et al²² examined the influence of implant bed preparation, using either Er:YAG laser ablation, piezoelectric surgery or drill osteotomy, on osseointegration of titanium dental implants after 4, 6, and 8 weeks and found that BIC in laser and piezoelectric osteotomy seem to be at least comparable to drill osteotomy.

Use of Lasers In Second Stage Uncovering Of Implants

The most friendly laser that can be for uncovering of implants is Er:YAG laser. Using a reduced water spray in order to decrease bleeding, it is possible to uncover the implant with diminished pain, even if bone is covering the implant. Using longer pulses causes haemostasis in the soft tissue, while shorter pulses enable the removal of bone without thermal side-effects. This is achieved without causing pain to the patient and without raising a flap. This is possible, of course, if there is sufficient attached gingiva and the crestal attached gingiva does not need to be replaced apically. When there is no harmful heating of the soft tissue, there is no retraction of tissue, so the impressions can be taken as soon as possible without delay.

Kurtzman GM presented a case report in which diode laser at 2.5 W in continuous mode was used in a circular motion, moving outwards until the entire cover screw was exposed (Figure 1).

The Diode Laser as an Adjunct to Implant Treatment

Safe cutting and hemostasis for improved workflow and outcomes

Gregori M. Kurtzman, *Inside Dentistry*. 2015;11(7):72-5.)



Figure 1

Use Of Lasers For Decontamination Of Implant Surface

A new indication of laser treatment might be the sterilisation of exposed implant surfaces to rehabilitate failing implants. The laser systems that are effectively used for this purpose are CO₂ laser and Er:YAG laser. Nd:YAG lasers have produced *in vitro* undesirable results, such as melting and increasing the roughness of the implant surface. Although Nd:YAG lasers significantly decrease bacteria, alterations to the implant structure occurred as well as significant increases in temperature²³. For these reasons, the application of the contact Nd:YAG laser for treatment of periimplantitis is contraindicated. In contrast to that, CO₂ lasers at a low-power setting are advantageous for periimplant procedures. They provide disinfection and significant bacterial reduction without causing any alteration to the implant structure.

A study by Deppe et al²⁴ compared CO₂ laser assisted implant decontamination vs conventional decontamination procedures. This study showed that implants treated with CO₂ laser decontamination exhibited statistically significant better clinical parameters than conventionally decontaminated implants. Promising results in the treatment of periimplantitis have also been demonstrated histologically by Takasaki et al²⁵ in their study compared the effect of Er:YAG laser and curettage on the periimplantitis and concluded that laser and conv. The study showed better results with a greater bone-to-implant contact percentages are obtained using the Er:YAG laser compared with the curette group. Kreisler et al²⁶ evaluated different lasers {Nd:YAG, Ho:YAG, Er:YAG, CO₂, and diode (gallium-aluminum-arsenide)} for implant decontamination. They concluded that Nd:YAG and Ho:YAG were not suitable for implant surface decontamination as they caused changes in the surface layers of implants and that CO₂ and Er:YAG could be used at low-power settings to avoid surface alterations, whereas gallium-aluminum-arsenide lasers did not cause surface changes.

Figure – shows decontamination of implant surface with Nd:YAG laser and Fig2 shows radiograph before the laser treatment and radiograph after the laser treatment of the same implant.

(The use of laser therapy for dental implant surface decontamination: a narrative review of *in vitro* studies. *Lasers Med Sci.* 2014 Nov;29(6):1977-85

Kamel MS, Khosa A, Tawse-Smith A, Leichter J.)

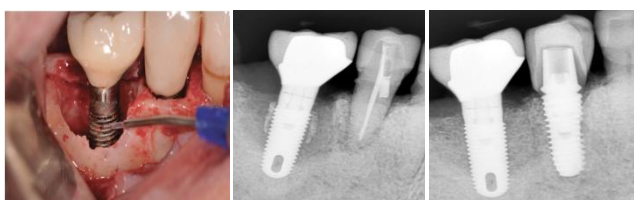


Figure 2

Laser Welding Of Implant Supported Metal Frameworks

The application of laser welding technology allows titanium to be welded predictably and precisely to achieve accurate fit of a milled framework. Laser energy results in localized heat production, thereby reducing thermal expansion. Unlike soldering, laser energy can be directed to a small area, making it possible to laser weld close to acrylic resin or ceramic. Neodymium:YAG (Nd:YAG) lasers are solid active medium lasers frequently used in dentistry to weld dental alloys. Advantages of laser welding include: (1) laser-welded joints are stronger than soldered joints; (2) localized heat is produced, thus avoiding expansion and distortion; (3) the need to fabricate a refractory cast is eliminated; (4) welding can be performed in close proximity with acrylic resin or ceramics^{27,28}. In one of the studies performed by Fornani C et al, two techniques to weld metals intraorally, the Nd:YAG laser welding and resistance spot welding, were compared for temperature rise in titanium bars and titanium implants during welding process and for the strength of soldered joint by two methods. The results confirmed that there is minimum rise in temperature with laser welding and also that strength of joint is more in laser welded implant framework²⁹. Reidy et al³⁰ have also reported the precision, fit of the laser-welded framework to 1-piece casting. A study by Bergendal and Plamqvist³¹ documented more fractures of artificial teeth on titanium-welded frameworks.

Laser Applications In The Dental Laboratory

Lasers have been used for deposition of hydroxyapatite (HA) thin films on titanium implants. Pulsed laser deposition (PLD) has proven to be a promising method to produce pure, crystalline and adherent HA coatings which show no dissolution in a simulated body fluid. Use of lasers for surface treatment of titanium castings for ceramic bonding have shown improved bond strength when compared to acid etching techniques which are commonly used.

Ayako et al applied our laser-assisted biomimetic (LAB) process to successfully achieve rapid single-step CaP precipitation on the surface of titanium metal, which is an important metallic biomaterial, by applying pulsed laser irradiation to the titanium substrate immersed in a supersaturated CaP solution. Precipitation occurred via the combined effect of laser surface modification and ambient heating.

(Laser-assisted biomimetic process for surface functionalization of titanium metal .Ayako Oyane a, Nao Matsuoka , Kenji Koga ,Yoshiki Shimizua, Maki Nakamura , Kenji Kawaguchi , Naoto Koshizaki , Yu Sogo , Atsuo Ito , Hidero Unuma . Colloids and Interface Science Communications.)

Energy Dispersive X-ray Analysis revealed that calcium and phosphate were detected after conducting LAB process(Fig 1a). Scanning electron microscopic images in Fig 1b showed that titanium surface deformed into a microscale grainy structure with sub-microscale asperity faces after conducting Laser Assisted Biometric (LAB) process.

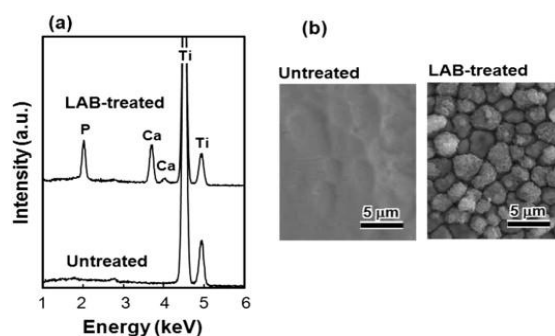


Fig. 3 Energy-dispersive X-ray analysis (EDX) spectra and (b) scanning electron microscopy (SEM) images of the untreated titanium substrate surface and that after conducting the LAB process

Jin-Tae Kim et al compared the effect of laser etching ,machining, airborne-particle abrasion, and acid etching on the bond strength between a titanium substrate and porcelain and concluded that the laser-etching surface treatment improves bond strength to a low fusing porcelain more as compared to acid-etching and machining surface treatment methods but was comparable in results to air abrasion method. The photomicrographs of the metal surface after debonding are presented in Figure All of the experimental groups exhibited small amounts of porcelain retained on the surface but airborne particle abraded and laser etched showed more of the porcelain attached to the metal surface.

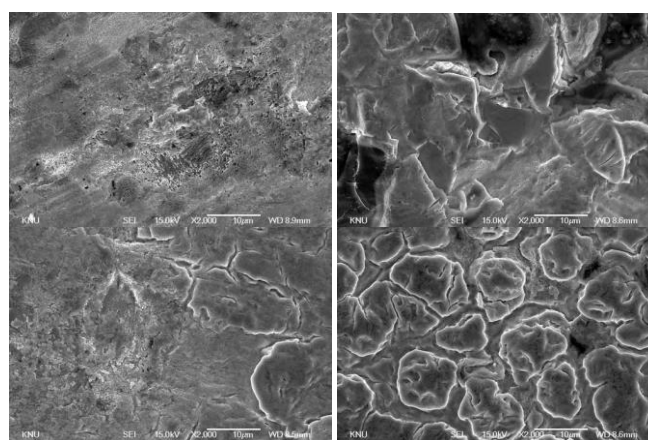


Figure 4: SEM photomicrographs of fractured metal surfaces after shear bond test. A-Machined, B-Air borne particle abraded, C-Acid etched , D-Laser etched.

(The effects of laser etching on shear bond strength at the titanium ceramic interface .**Jin-Tae Kim, DDS,a and Sung-Am Cho** . J Prosthet Dent. 2009 Feb;101(2):101-6.)

III. Conclusion

Lasers have become a ray of hope in dentistry. Lasers have made a tremendous impact on the delivery of dental care and will continue to do so as the technology continues to improve and evolve. When used effectively and ethically, lasers are an exceptional modality of treatment for many clinical conditions that dentists treat on a daily basis. The results of implant procedures carried out with lasers seem to be promising only when correct laser with correct wavelength and power settings is used. Not only this, the clinician should have extensive knowledge of laser physics and laser tissue interactions before any laser treatment is carried out. Lasers have made a tremendous impact on the delivery of dental care and will continue to do so as the technology continues to improve and evolve. Lasers can prove to be a blessing in disguise if used safely and properly

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